ROAD MANAGEMENT AND DECISION SUPPORT SYSTEM (RMDS) AS A TOOL FOR ROAD ASSETS MANAGEMENT IN CAMBODIA

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ABSTRUCT
Cambodia's road network, like any other physical infrastructure in the country, has been neglected until recently. The Ministry of Public Works and Transport has been working not only constructing new road sections but also making all efforts to maintain the existing road network in an efficient, safe and passable state. Currently a significant portion of the road network is only passable by motorcycle due to broken bridges, constricted road widths etc. To plan any development (new construction) or maintenance work it is imperative to know the existing physical and condition characteristics.
The road maintenance stakeholders have largely been working with information that is mostly outdated and not reflective of the current network status. It was therefore agreed that a road data bank be established that would not only enhance with planning future development projects but would also assist in road maintenance planning (budget requirements).
A road management and decision support system (RMDS) through the location referencing and condition survey (LRCS) contract was developed in 2004 by financial support from the World Bank. **The RMDS** is to become instrumental in providing current inventory and condition characteristics to the Road Assets Management Office and other stakeholders and assist in determining road maintenance budgets.

1. DECISION SUPPORT SYSTEM OVERVIW

While the LRCS project is primarily about data capture and population of a geographic database, the applications implemented to support the processing of survey data, transformation of data to HDM-4 and basic reporting of road statistics and maps are extremely flexible in their design. As such the solution implemented for the LRCS Project can in the future be extended to support more advanced management planning decisions.

The figure below shows how the systems being implemented for the LRCS project can be extended to become a comprehensive Road Management Decision Support (RMDS) system.

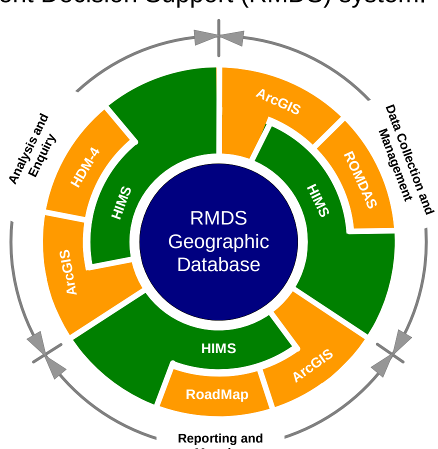

Figure 1: Road Management Decision Support (RMDS) Schematic

The above schematic has the RMDS Geographic Database at its hub. Working around the outside of the circle we can see how data flows in and out of the data repository through the various applications. For example:

Data Collection and Management

- Condition data is collected with ROMDAS, processed by HIMS before reaching the database.
- HIMS is used to edit and update network and road attribute data.
- ArcGIS is used to maintain the spatial data in the geographic database directly and via HIMS …

Analysis and Enquiry

- Data is exported by HIMS to a format that can be used by HDM-4.
- HIMS can be used to complete data queries such as find all sealed roads with roughness > 6 IRI.
- ArcGIS can be used for spatial analysis

Reporting and Mapping

- RoadMap provides an intuitive interface to a subset of the geodatabase exported from HIMS.
- HIMS can be used to extract basic reports on condition, lengths, location and inventory.
- ArcGIS can be used to produce thematic maps of road condition

2. ROMDAS FIELD SURVEY

2.1 System Overview

A robust and flexible data collection system was used to undertake the majority of the data collection. This consisted of ROad Measurement Data Acquisition System (ROMDAS) and StarFIRE GPS.

ROMDAS is a robust and flexible data capture system for both developed and developing countries. Its modular design makes it flexible for use by a wide range of users. The core ROMDAS hardware items that were used for this project were:

ROMDAS 9000 (hardware interface, switch and minor hardware)	Direct digitising video system (camera and firewire card)
2 x Bump Integrators	High resolution Distance Measurement Instrument (DMI)
GVH Gyroscope	Programmable Keyboard (58 Key)

The ROM-WIN software (version 2.1.6.D) was used to link and communicate with the above components.

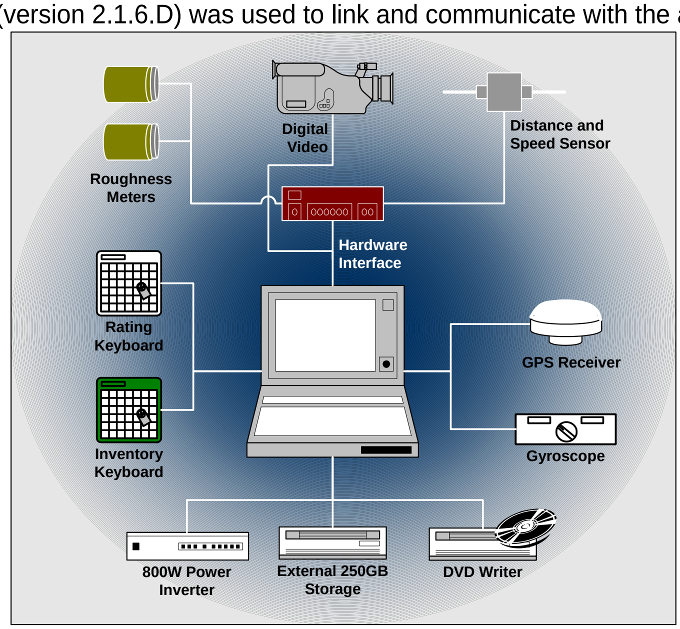

Figure 2: ROMDAS System Used for LRCS Project

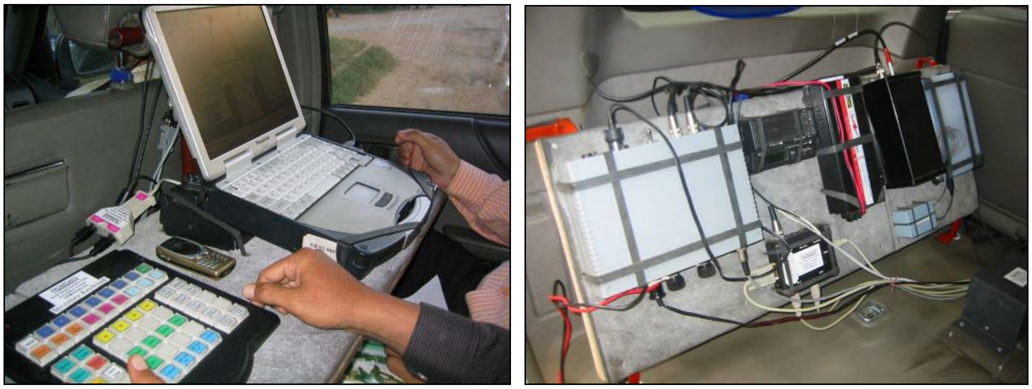

Figure 3: ROMDAS Vehicle Installation

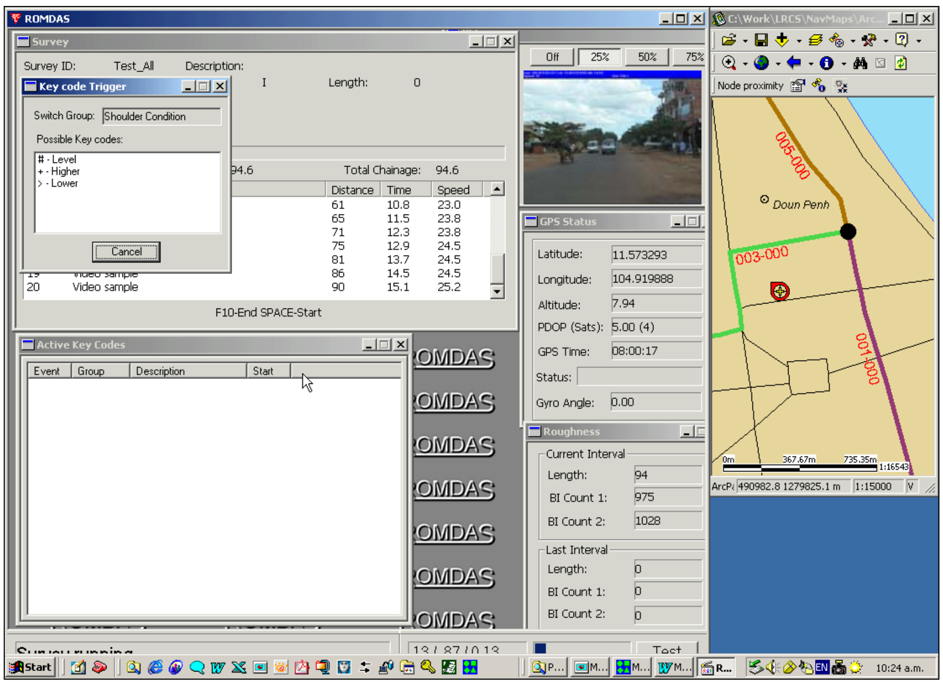

Figure 4: ROMDAS Software Running on Laptop

The location referencing[1] of the nodes and centreline by ROMDAS was measured using the NavCom SF-2050G "StarFire" real-time differential Global Positioning System (dGPS). This dGPS system provides the highest real-time single-receiver accuracy available, typically achieving decimeter-level accuracy for both horizontal and vertical position. This equipment is also a standard dGPS system used with the ROMDAS system, so is already integrated within all survey system components and is field-tested and proven.

2.2 Road Inventory Attributes

Six road inventory attributes were observed and recorded (using the programmable keyboards) from the moving vehicle. These are summarised in Figure 5 below.

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[1] Refer to the RMDS User Guide for information on the road referencing method used for this project

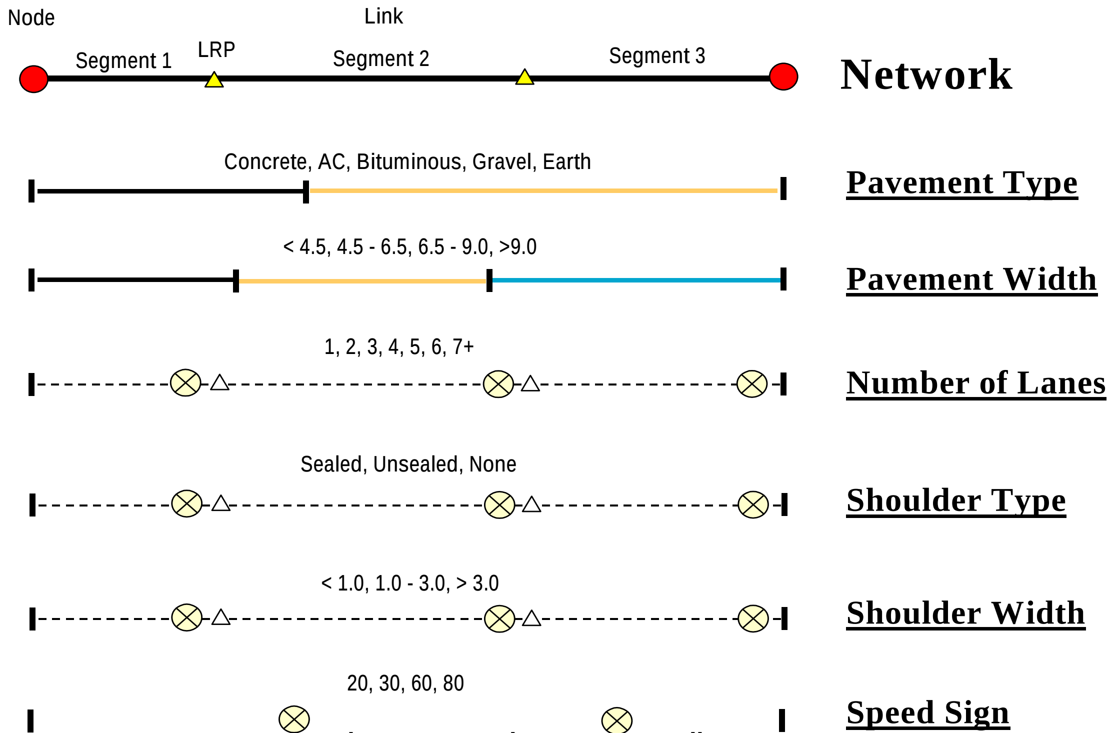


Figure 5: Road Inventory Attributes

Pavement Type and Width were recorded as continuous events (whenever there was a change) while the "typical" number of lanes, shoulder type and width were recorded at the end of each segment and assumed to be uniform for that segment. Speed signs were recorded wherever seen and entered as a point event.

2.3 Road Condition Attributes

Six road condition attributes were observed and recorded from the moving vehicle. These are summarized in Figure 6 below.

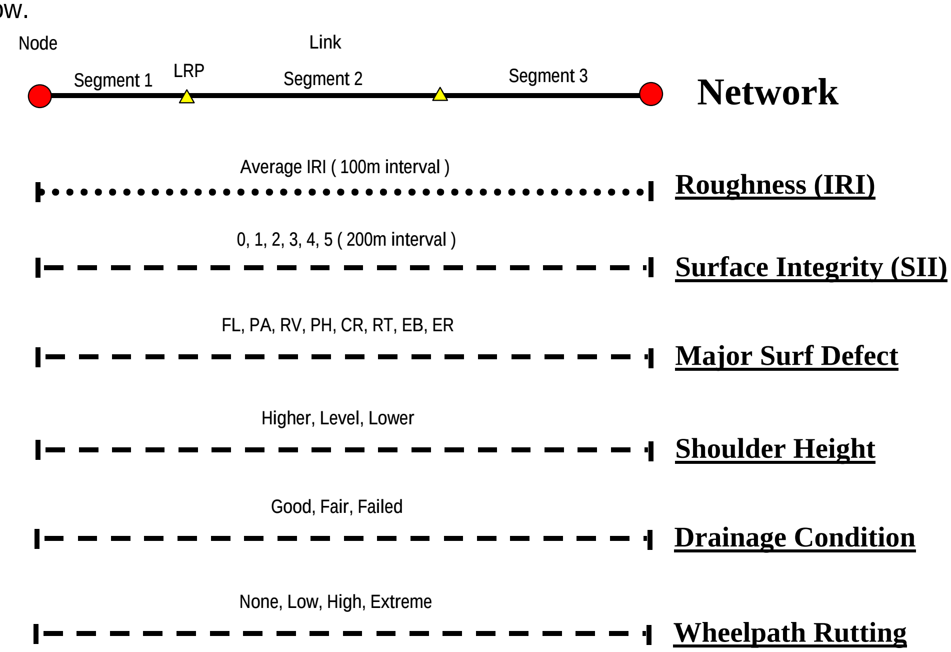


Figure 6 : Road Condition Attributes

Road roughness (IRI) was recorded automatically every 100m while the SII, major defect type, shoulder height, drainage condition and rut level were recorded at the end of each 200m section and assumed to be uniform for that section. During the post-processing adjacent sections with the same rating were combined.

2.4 Traffic Survey

Moving Traffic Survey

During the ROMDAS survey, any vehicles passed in the opposing direction of travel were recorded in three classes, namely:

- Heavy,
- Medium, and
- Light

This information was then used in conjunction with the manual counts to determine and estimated annual daily traffic volume for each road link.

Manual Traffic Classification Counts

Traffic manual 12-hr classification counts were carried out at 31 sites around the network. This data was then used to calibrate the moving traffic survey information to calculate an equivalent Average Daily Traffic volume.

2.5 Bridge and Culvert Survey

The bridge and culverts were surveyed using motorcycles.

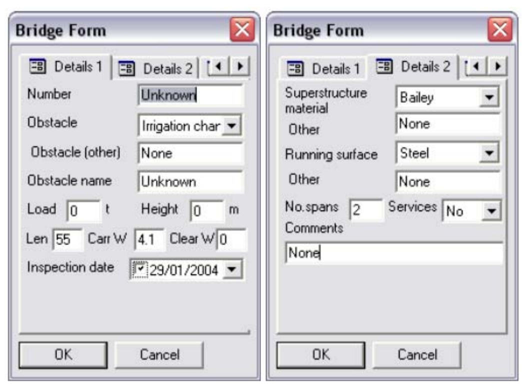


Figure 7: Bridge and Culverts Survey on Motorbikes

The teams were equipped with a handheld survey system consisting of:

- iPAC 3950 with 64Mb SD
- Predator 2007s iPac Housing
- Garmin GPS 76
- Sony DSC-P32 digital camera (256Mb Mem.)
- ArcPad software

The teams stopped at each structure and recorded the following general information about each structure:

- GPS coordinates of culvert and start/end of bridge
- Digital photos of structure (3-6 for bridges, and 1-3 for culverts)
- Attributes about the bridge and culvert.

The attributes were entered directly into a form/database designed in ArcPAD software and loaded on the iPAC PDA devices. As with the ROMDAS surveys, the motorbike teams had real-time navigation using the GPS and ArcPAD software loaded on the PDAs.

3. NETWORK SUMMARY STATISTICS AND MAPS

3.1 Cambodia Road Network

The Cambodia network survey was tasked with surveying all National and Provincial roads in the Kingdom.

Table 1 below summarise the total network length as captured during the LRCS Project. The figures have been extracted from the RMDS database using HIMS standard queries.

Table 1 Cambodia Road Network Statistics from LRCS Survey

Road Class	Length Surveyed		Length	
	Paved	Unpaved	Unsurveyed*	Total
National	1,543.4	444.6	-	1,988.0
Secondary National	398.7	1,808.9	202.0	2,409.6
Provincial	122.5	5,986.5	604.7	6,713.6
Total	**2,064.5**	**8,240.0**	**806.7**	**11,111.2**

**Unsurveyed roads were identified within the GIS once survey data processed – they were generally impassable sections or sections not identified during the preplanning activities.*

Figure 8: National and Provincial Network

3.2 Network Roughness

Road roughness is expressed in terms of the International Roughness Index (IRI) which is an index computed from a longitudinal profile measurement using a quarter-car simulation at a simulation speed of 80km/h. Expressed in units of m/km.

To understand the IRI units in more subjective terms we have reproduced the diagram below from the "little book of roughness".

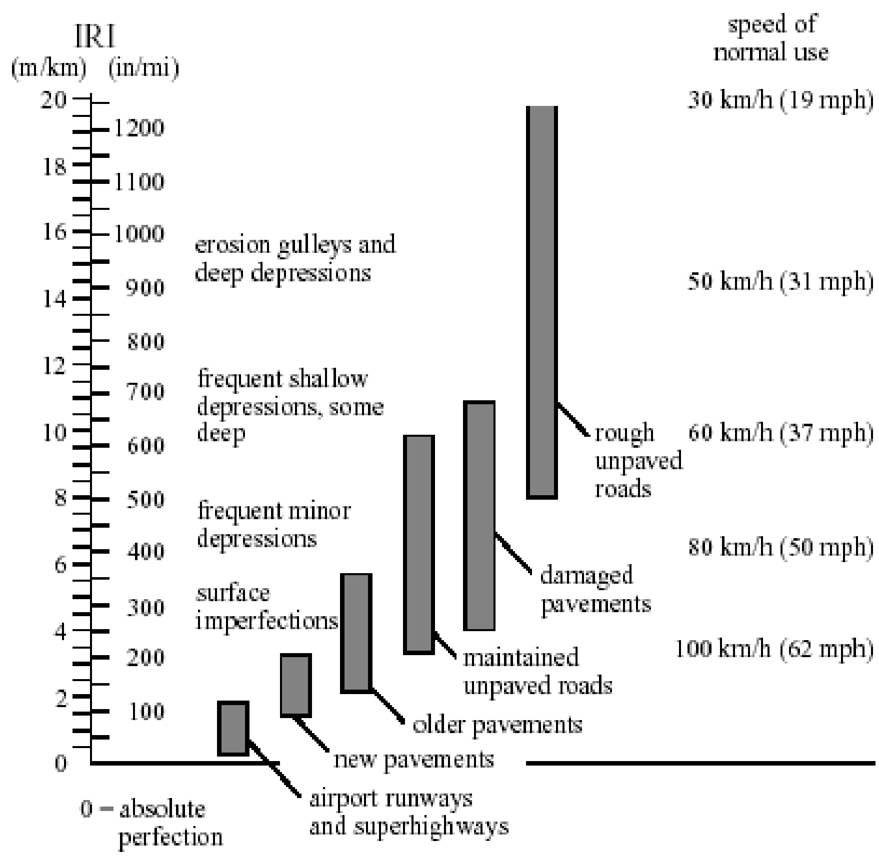


Figure 9: IRI Spectrum (from "Little Book of Roughness")[2]

Roads with an IRI > 8 are generally considered to be in poor condition while roads with an IRI less than 4 can be considered as very good.

Figure below shows the final distribution of roughness readings taken on the sealed network. It shows that 80% of sealed roads have an IRI less than 8.

[2] Sayers M.W and Karamihas S.M, *Little Book of Roughness*, University of Michigan, Sept 1998.

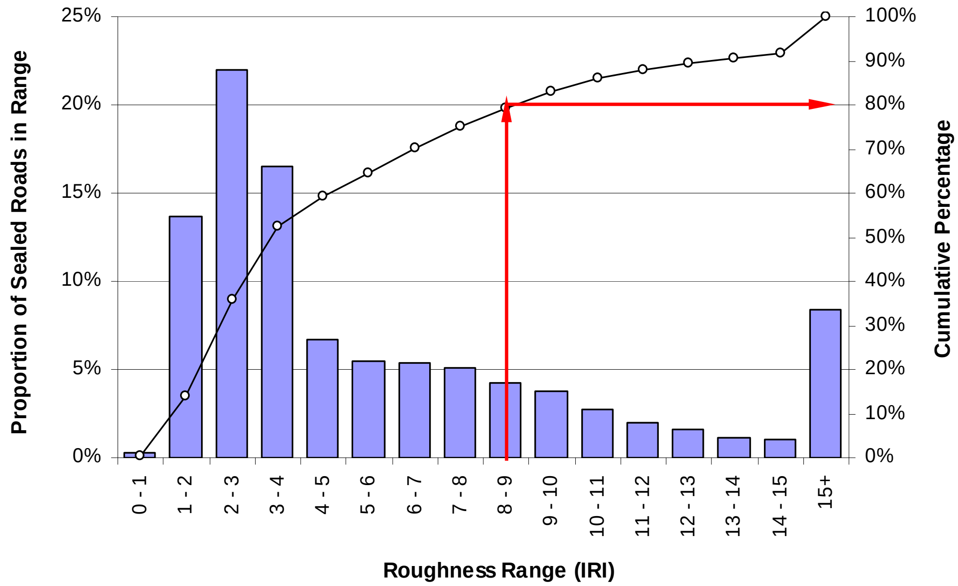


Figure 10: Final Roughness Distribution (Sealed Network)

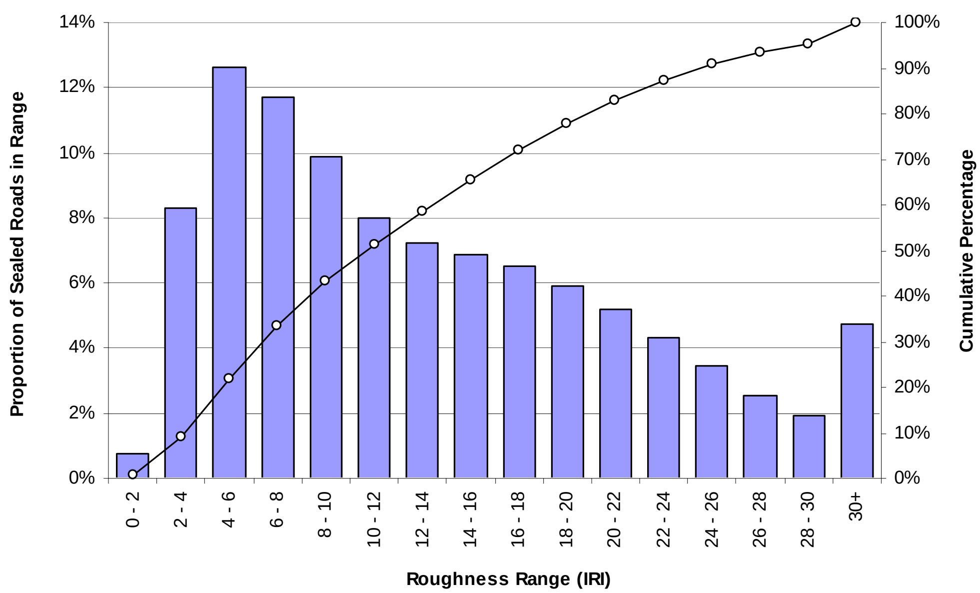
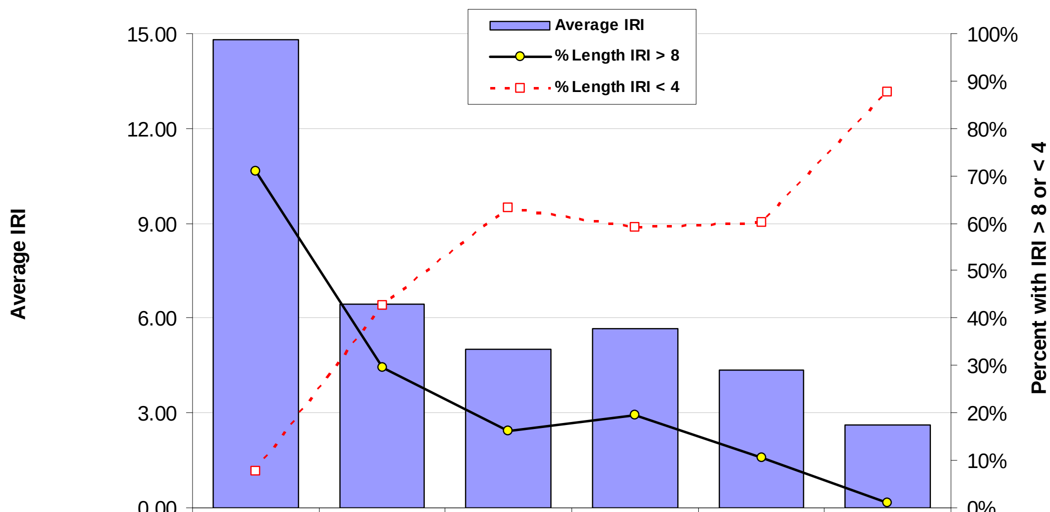


Figure 11: Final Roughness Distribution (Unsealed Network)

The relational nature of data held within the RMDS geodatabase means that we are able to query the relationship between different road attributes to make more informed decisions and comparisons, for example:

- What is the average roughness of sealed roads in the Siem Reap province?
- Are roads with greater than 5,000vpd in better condition to roads with < 1,000vpd?
- What sections of road are carrying greater than 5,000vpd and have a width less than 5m and roughness IRI > 8?

Figure 12 below presents the relationship between road roughness (expressed as IRI) and traffic for all sealed roads.



	<500vpd	500-1000vpd	1000-2000vpd	2000-3000vpd	3000-4000vpd	>4000vpd
Average IRI	14.81	6.42	5.02	5.66	4.34	2.62
Length in Band	243.28	532.63	576.32	569.27	63.58	104.60
% Length IRI > 8	71%	30%	16%	20%	11%	1%
% Length IRI < 4	8%	43%	63%	59%	60%	88%

Summary Statistics Table

Figure 12 Roughness by Traffic Volume (Sealed Network)

From a road management view point the figure above shows that roads with higher traffic volumes are currently in a better condition (smoother = lower IRI) to roads with lower traffic. This is good management practice as it is these roads that will return the most benefits to the road users if they are kept in good condition. When establishing maintenance intervention standards (e.g. at what level it becomes 'economic' to do an overlay) it is necessary to consider the class of road that standard is being applied to.

3.3 Network Surface Condition

The surface condition of sealed roads has been expressed in terms of the Surface Integrity Index (SII). Table 2 summarises the SII ratings in terms of possible maintenance needs for the pavement.

Table 2 Surface Integrity Category Definition (sealed roads)

Description of Surface Condition	Sealed	
	SII	% in Range
Excellent integrity	0	**36%**
Initiation of distress has occurred, some recurrent maintenance may be needed.	1	**26%**
Sufficient distress to warrant preventative maintenance (*i.e.* resurfacing)	2	**16%**
Resealing or resurfacing warranted under corrective policy	3	**11%**
Rehabilitation including possible strengthening likely to be warranted	4	**4%**
Reinstatement or reconstruction is necessary, possibly in localised areas	5	**6%**

3.4 Overall Sealed Road Condition

The following table may be used to report road condition as four condition bands. Each class is based on an assessment of roughness and surface condition and is useful when comparing the relative condition of pavement over time or when comparing data between road classes or provinces as in Figure 13.

Table 3 Overall Road Condition Categories Definition (sealed roads)

Class	Description of Surface Condition	Roughness	% Defect	% in Range
Good	Smooth roads with no signs of surface distress - no maintenance	IRI<3	0%	20%
Fair	Smoother roads showing signs of distress - routine maintenance or possible resurfacing	IRI<5 *or* 3<IRI<5	<20% 0%	34%
Poor	Moderately rough roads with distress - probable resurfacing or possible rehabilitation required	5<IRI<10 *or* IRI<10	<20% >20%	28%
Very Poor	Rough roads or roads with considerable distress - probable rehabilitation or smoothing/resurface	10<IRI<15 *or* IRI>10	<20% >20%	18%

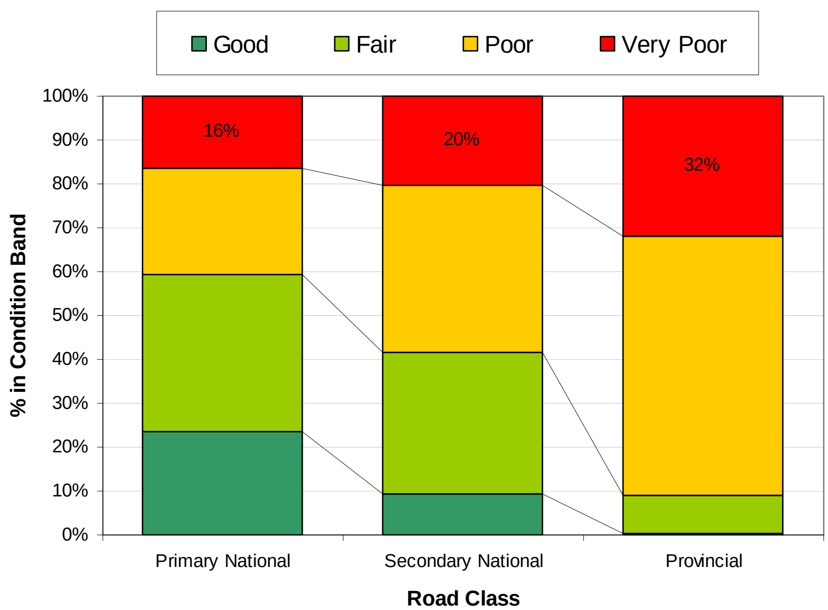


Figure 13: Relative Condition of Network (By Road Class)

4 APPROACH FOR ESTIMATING ROAD MAINTENANCE FUND

Background

RMDS system consists of the following two sub-systems of a typical road management system:

Road Information System (RIS) – includes inventory and condition attributes for national roads (one digit), other national roads (two digit roads) and provincial roads of more than 11,000 centerline kms. To develop RMDS system, field data was collected based on World Bank's Information Quality Level (IQL) -3 for sealed roads and IQL-4 for unsealed roads.

Pavement Management System (PMS) – To estimate annual road maintenance funds and to finalize multi-year forward works programmes. RMDS uses World Bank's HDM-4 program as the analysis engine for estimating maintenance fund.

The outputs from RMDS can be used for preparing annual maintenance programmes. However, the information stored in RMDS should be kept updated and the quality of the data should be gradually increased for more reliable outputs.

Maintenance Analysis

Considering approximate 20:80 split of the paved and unpaved roads in Cambodia, separate analysis was undertaken for paved and unpaved analysis sections. HDM-4 programme analysis with unlimited and capped budget was considered for paved roads maintenance funds estimation. For unpaved roads, per-km cost approach was used. Per-km costs are determined from the HDM-4 life cycle cost analysis.

Maintenance Treatments

Maintenance includes all activities needed to keep a road operating indefinitely[3]:

- Routine maintenance (restoring drainage, filling potholes and cracks, maintaining edges etc);
- Periodic maintenance (resealing, thin overlays with pre-seal repairs, about every 5 years, to rejuvenate the surface); and,
- Rehabilitation (heavy overlay, about 15 years, to restore smoothness and durability).

Reconstruction, often considered as a capital expenditure, is used where resealing or rehabilitation is no more effective. That means, the road section is so deteriorated that a reconstruction can only restore it back to the serviceable condition. It is recommended to estimate the total maintenance fund required and later divide into maintenance budget and capital budget.

Maintenance Intervention Criteria

The ideal intervention criterion is to keep the network in 'good' condition always. However, this may not be practically possible even in highly developed and industrialized countries due to budget constraints. Maintenance criteria should not be too 'optimistic'. Using current maintenance practice would also do no good, particularly when significant backlog already exists. Somewhere between the current maintenance intervention level and optimistic level is recommended initially. One should consider the targeted levels of service and allowed time frame for finalizing the maintenance intervention levels.

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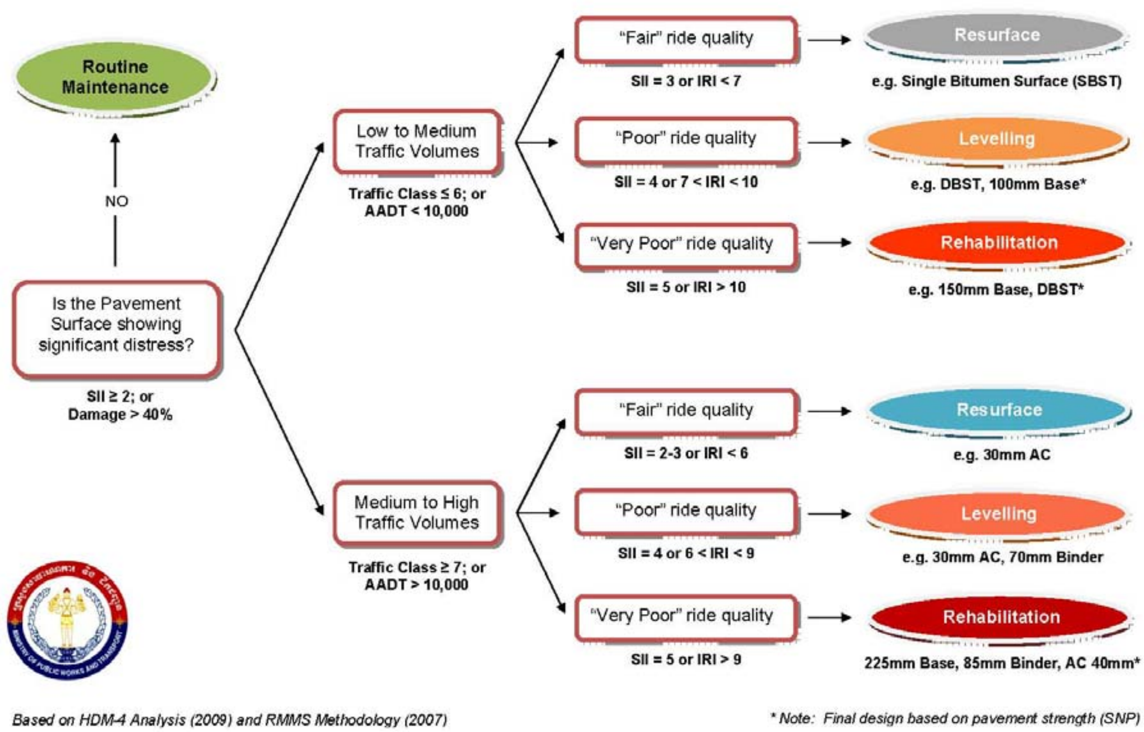
[3] *Road Funds and Road Maintenance – An Asian Perspective, Asian Development Bank, July 2003*

Figure 14: Treatment Logic for Identifying Candidate Sections



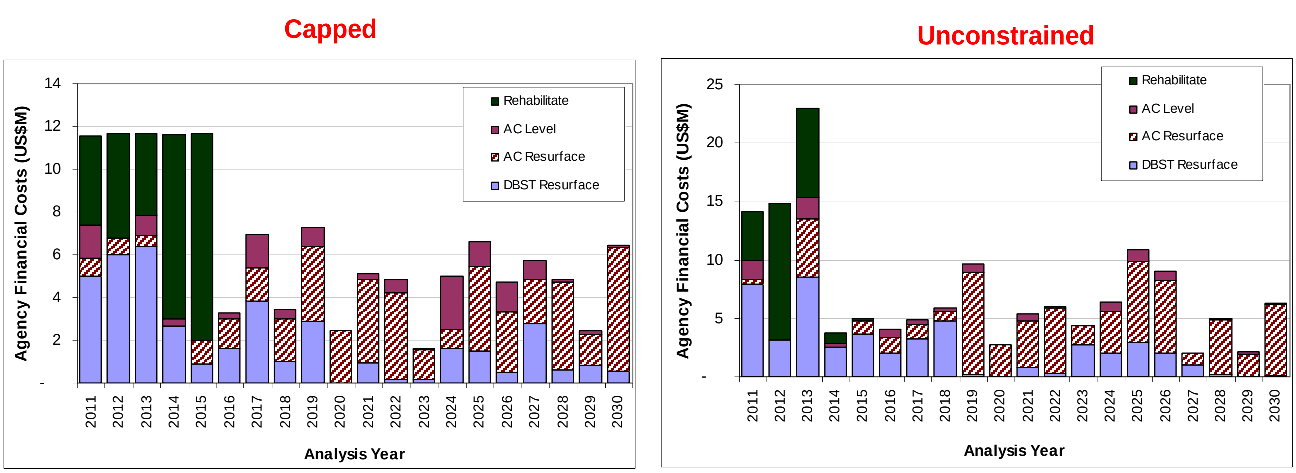


Figure 15: National Road Periodic Maintenance from HDM-4 Analyses

Reference:

Location Referencing and Condition Survey Final Report 2004 prepared by MWH